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Process for manufacturing Al-Mg alloy sheets for press forming.

This invention relates to a process for manufacturing Al-Mg alloy sheets with high Mg content for press forming. The composition of an Al-Mg alloy slab consists of 5 to 10 wt.% of Mg, 0.0001 to 0.01 wt.% of Be, totally 0.01 to 0.2 wt.% of one or more than two species out of Mn, Cr, Zr and V, 0.005 to 0.1 wt.% of Ti, or both 0.005 to 0.1 wt.% of Ti and 0.00001 to 0.05 wt.% of B, Fe and Si as impurities respectively with the content restricted to be less than 0.2 wt.%, and the remainders consisting of other inevitable impurities and Al. The maximum grain diameter of the alloy slab is less than 1000 μm . The homogenization conditions of the alloy slab are set such that a temperature for homogenization is in the range of 450 to 540°C and a time for the homogenization is not more than 24 hrs, and the conditions for the hot rolling are set such that a hot mill entrance temperature is in the range of 320 to 470°C and each reduction per pass of at least the initial three times of rolling pass is not more than 3%. This process improves the hot workability of Al-Mg alloy sheets with high Mg content, and cracks are prevented from being generated at the time of hot rolling to improve the productivity. When 0.05 to 0.8 wt.% of Cu is contained in the Al-Mg alloy slab, in addition to the above-mentioned component compositions, the strength and elongation of the resultant alloy sheets can be further improved.

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BACKGROUND OF THE INVENTION

Field of the Invention:

5 This invention generally relates to a process for manufacturing Al-Mg alloy sheets, and more particularly to a process for manufacturing Al-Mg alloy sheets suitable to sheets for press forming of auto body panels, air cleaners and oil tanks or like products which require strength and high formability.

Description of the Prior Art

10 In general, cold rolled steel sheets have been largely used as sheets for press forming of auto body panels or the like. In recent years, however, there has been a great demand that aluminum alloy sheets are used instead of cold rolled steel sheets in order to make auto bodies lightweight for improving the fuel consumption thereof.

15 In a prior art, as for an aluminum alloy sheet for press forming, which requires strength and high formability, there is known O stock of Al-Mg alloy 5052 (chromium alloy containing 2.5 wt.% of Al and 0.25 wt.% of Mg), O stock of Al-Mg alloy 5182 (manganese alloy containing 4.5 wt.% of Al and 0.35 wt.% of Mg), T4 stock of Al-Cu alloy 2036 (magnesium alloy containing 2.6 wt.% of Al, 0.25 wt.% of Cu and 0.45 wt.% of Mn) or the like.

20 Of all these items described above, the Al-Mg alloy sheets are excellent in both formability and strength and often used as a member subjected to strict press forming.

Normally, the Al-Mg alloy sheets for press forming are manufactured by a process including the following steps of production of slabs for rolling, homogenization, hot rolling, cold rolling and final annealing. Additionally, an intermediate annealing step is carried out on the way of the cold rolling step, if necessary. In the case where such sheets particularly requires flatness, a straightening step is often carried out by a tension leveler, a roller leveler, skin pass rolling or like means after the annealing.

25 The conventional Al-Mg alloy sheets for press forming manufactured as described above are relatively abundant in ductility in comparison with that of other aluminum alloy sheets. However, the elongation of the Al-Mg alloy sheet is approximately 30% at most, whereas the elongation of a cold rolled steel sheet is 40%. Therefore, particularly with respect to the formability where the elongation is an influencing factor in stretch forming, bending and flanging, the Al-Mg alloy sheet is inferior to the cold rolled steel sheet.

30 On the other hand, it has already been known that the elongation of the Al-Mg alloy sheet is improved in proportion to Mg content therein. In recent years, it has been thus examined the manufacture of Al-Mg alloy with high Mg content, which contains Mg more than that of the prior art Al-Mg alloy sheet (2.5 to 5.0 wt.% of Mg) in order to improve the elongation.

35 For instance, according to the research of the present inventors, it is necessary to set the Mg content to 6 wt.% in order to manufacture such an Al-Mg alloy sheet as to have the elongation of 35%, and it is also necessary to set the Mg content to 8 wt.% in order to manufacture such an Al-Mg alloy sheet as to have the elongation of 40%. (See Japanese Patent Application No. 4-102456).

40 However, when such Al-Mg alloy sheets with high Mg content were manufactured in an industrial scale, it has been found that cracks are often generated during hot rolling, and therefore, the subsequent rolling becomes impossible in some cases. In other words, even though the sheets may be continued rolling under the condition that the cracks are often generated, it would be necessary to cut out the crack portions in the subsequent process. As a result, the yield of the product is lowered to reduce the production efficiency extremely.

SUMMARY OF THE INVENTION

45 It is an object of the present invention to provide a process for manufacturing Al-Mg alloy sheets for press forming, which can improve the hot workability of such Al-Mg alloy sheets with high Mg content as to contain not less than 5 wt.% of Mg, and can improve the productivity by preventing the generation of cracks at the time of hot rolling.

50 A process for manufacturing Al-Mg alloy sheets for press forming of the present invention comprises the steps of homogenization, hot rolling, cold rolling and final annealing of an Al-Mg alloy slab or intermediate annealing on the way of the cold rolling, wherein the composition of the Al-Mg alloy slab contains 5 to 10 wt.% of Mg, 0.0001 to 0.01 wt.% of Be, totally 0.01 to 0.2 wt.% of one or more than two species out of Mn, Cr, Zr and V, 0.005 to 0.1 wt.% of Ti or both 0.005 to 0.1 wt.% of Ti and 0.00001 to 0.05 wt.% of B, Fe and Si as impurities respectively regulated to be less than 0.2 wt.% and the remainders consisting of other inevitable impurities and Al; the maximum grain diameter of the Al-Mg alloy slab is less than 1000 μm ; the conditions for homogenization of the Al-Mg alloy slab are set such that a temperature for homogenization is in the range of 450 to

540°C and a time for homogenization is not more than 24 hours; and the conditions for hot rolling are set such that a hot mill entrance temperature is in the range of 320 to 470°C and each reduction per pass of at least the initial three times of rolling pass is not more than 3%.

When the strength and elongation of the Al-Mg alloy sheets are desired to be further improved, 0.05 to 0.8 wt.% of Cu is preferably contained in the Al-Mg alloy slab in the manufacturing process, in addition to the component compositions described above.

With reference to each element other than aluminum contained in the composition of the aluminum alloy slab described above, the detailed description will be given about the reasons why these elements are selected and why the contents thereof are respectively restricted.

Mg is added in order to provide the strength and elongation to the resultant aluminum alloy sheet.

When Mg content is less than 5 wt.%, the elongation of the alloy sheet is insufficient (less than 30%). On the other hand, when the Mg content exceeds 10 wt.%, the hot workability of the alloy slab is rapidly lowered and it becomes hard to manufacture the alloy sheet.

Be is added in order to prevent the oxidation of molten metal at the time of melting and casting of the alloy and to prevent both Mg loss and superficial change of color due to the oxidation of the slab under homogenization.

When Be content is less than 0.0001 wt.%, Be has insufficient effect. On the other hand, when the Be content exceeds 0.01 wt.%, a problem of toxicity arises.

Mn, Cr, V and Zr are added in order to improve the hot workability of the alloy.

As a result of extensive researches and investigations by the present inventors, it is found that in the Al-Mg alloy with high Mg content, the grains of the slab are coarse prior to hot rolling, namely, after homogenization, and when the maximum grain diameter thereof becomes not less than 1000 μm , the hot workability of the alloy is extremely lowered.

Furthermore, it is found that the Al-Mg alloy with high Mg content controls the generation of the coarse grains under homogenization by the addition of Mn, Cr, V and Zr, and thus the hot workability thereof is remarkably improved.

In brief, Mn, Cr, V and Zr are precipitated into an aluminum matrix as extremely fine precipitates in the temperature-up process for the homogenization of the alloy slab, and these fine precipitates control the growth of the coarse grains (secondary recrystallized grains) under homogenization.

Totally 0.01 to 0.2 wt.% of one or more than two species out of Mn, Cr, V and Zr is added. When the content thereof is less than 0.01 wt.%, their effect is not sufficiently shown. On the other hand, when the content exceeds 0.2 wt.%, coarse intermetallic compounds are formed to lower the elongation of the alloy.

Ti or both Ti and B are added in order to homogeneously make an alloy slab structure finer so as to adjust the maximum grain diameter to be less than 1000 μm .

When Ti content is less than 0.005 wt.%, Ti has insufficient effect. On the other hand, when the Ti content exceeds 0.1 wt.%, coarse intermetallic compounds are formed to lower the elongation of the alloy.

On the other hand, B coexists with Ti to further enhance the effect of making the alloy slab structure finer, it is desirable to add 0.00001 to 0.05 wt.% of B.

When B content is less than 0.00001 wt.%, B has insufficient effect. On the other hand, when the B content exceeds 0.05 wt.%, coarse TiB_2 compounds are formed to lower the elongation of the alloy.

Both Fe and Si are impurities in this alloy, and each content of Fe and Si should be regulated to be less than 0.2 wt.%.

When each content of Fe and Si is not less than 0.2 wt.%, Fe and Si are continuously crystallized out of solution in a grain boundary as eutectic constituents at the time of casting, and grain boundary strength in hot rolling is lowered to cause the cracks in the alloy sheet. In addition, not only the elongation but also the formability of the finally annealed sheet is lowered.

When the strength and elongation of the alloy sheet are desired to be further improved, Cu should be added in the range of 0.5 to 0.8 wt.%.

When Cu content is less than 0.05 wt.%, Cu has insufficient effect. On the other hand, when the Cu content exceeds 0.8 wt.%, the hot workability of the alloy is rapidly lowered and it becomes difficult to manufacture the alloy sheet.

If the total content of Zn and other inevitable impurities is not more than 0.3 wt.%, there is no particular problem so far as the effects of the invention are concerned.

Now, the detailed description will be given with respect to the reason why the manufacturing conditions are selected as described above in the process for manufacturing the aluminum alloy sheets in accordance with the invention.

First of all, each aluminum alloy slab having the above-mentioned component composition and the maximum grain diameter of less than 1000 μm is homogenized at temperatures of 450 to 540°C and for not more

than 24 hours so as to prevent the maximum grain diameter thereof from being not less than 1000 μm .

When the maximum grain diameter of the alloy slab becomes not less than 1000 μm , the resultant stress concentration on the grain boundary becomes remarkable to cause grain boundary breakage in the subsequent hot rolling. Therefore, the cracks resulting from hot rolling become remarkable and it becomes impossible to manufacture the alloy sheets.

Finer the grains of the alloy slab are, the more the hot workability is improved. Accordingly, the maximum grain diameter of the grains is desirably not more than 200 μm .

Homogenization is carried out in order to homogenize not only the distribution of the solute atoms of the slabs but also the annealed alloy sheet structure and to improve the strength and elongation of the alloy sheets for press forming. When a homogenization temperature is less than 450°C, the resultant homogenization effect becomes inadequate. When the homogenization temperature exceeds 540°C or the homogenization time exceeds 24 hours, the grains would be grown coarser (i.e., secondary recrystallized grains), and the maximum grain diameter becomes not less than 1000 μm to lower the hot workability of the alloy. In the case where the slab structure is coarse before homogenization, that is, after casting, the grains could not be made finer even though any further homogenization might be carried out. Therefore, it is necessary to make the slab structure finer in advance by the addition of Ti or both Ti and B.

As described above, the homogenized aluminum alloy slab having the maximum grain diameter of less than 1000 μm is subsequently subjected to hot rolling.

In industrial hot rolling, the slab having a thickness of 300 to 700 mm is normally processed into the hot rolled sheet having a thickness of 2 to 10 mm by the several ten times of repetitive rolling pass. In the hot rolling of Al-Mg alloy with high Mg content, cracks due to hot rolling can be easily generated at the first or the initial second to fifth rolling pass.

Furthermore, supposing that the Al-Mg alloy with high Mg content may not occur any large cracks due to rolling at the initial hot rolling pass, the fine cracks generated at the initial hot rolling pass gradually gets to grow up largely by the subsequent rolling pass and often develops into larger cracks at the latter-half rolling pass or the final rolling pass.

According to the hot rolling process in the manufacturing process of the invention, it is possible to entirely eliminate these cracks due to hot rolling by setting the hot mill entrance temperature to be in the range of 320 to 470°C and also setting each reduction per pass of at least initial three times of rolling pass to be not more than 3%.

When the hot mill entrance temperature for hot rolling is less than 320°C, the deformation resistance of the alloy slab becomes larger to increase the load required for rolling, and thus the industrial rolling becomes difficult.

On the other hand, when the hot mill entrance temperature exceeds 470°C, the cracks due to rolling are readily generated.

The reason why each reduction per pass of at least the initial three times of rolling pass is set to be not more than 3% is that the cracks due to hot rolling are prevented by applying a reduction as lower as possible at the initial rolling pass which might most easily generate the cracks due to hot rolling.

When each reduction per pass at the initial three times of rolling pass exceeds 3%, the excessive stress is applied to the grain boundary at the time of rolling to be in excess of the grain strength. As a result, grain boundary breakage is caused to generate the cracks due to hot rolling. Assuming that such a hot rolling process may be adopted, the cracks due to hot rolling may be generated when the maximum grain diameter of the homogenized alloy slab is not less than 1000 μm .

There is no need to set each reduction per pass to be not more than 3% after the lapse of the initial three times of rolling pass (on and after the fourth rolling pass). Thus, each reduction per pass may be increased so as to improve the productivity.

The alloy sheet subjected to hot rolling under the rolling conditions described above is subsequently subjected to cold rolling or intermediate annealing on the way of the cold rolling to be reduced in a desired thickness. Then, the resultant sheet is subjected to final annealing to give an Al-Mg alloy sheet for press forming and having a thickness of approximately 0.8 to 2.0 mm.

The Al-Mg alloy sheet thus obtained by the manufacturing process of the invention described above is particularly excellent in both strength and elongation in comparison with those of the Al-Mg alloy sheet manufactured by the prior art process, and preferably used as a sheet for press forming of auto body panels or the like.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Hereinafter will be described a process for manufacturing Al-Mg alloy sheets for press forming according

to the invention in detail on the basis of the following examples.

First Example

As a first example of the invention, Al-Mg alloy sheets for press forming were manufactured as follows. Firstly, aluminum alloys having the compositions of alloy samples Nos. 1 to 22 shown in Tables 1 and 2 were subjected to DC casting (thickness: 500 mm, width: 1500 mm and length: 5000 mm) by a normal process. Then, each of the resultant alloy slabs was homogenized at 490°C for 1 hr., and then subjected to hot rolling up to 5 mm in thickness under the following conditions.

Incidentally, the alloys of alloy samples Nos. 1 and 3 to 5 have the corresponding compositions to Claim 1 of the manufacturing process according to the invention. The alloys of alloy samples Nos. 2 and 12 to 16 have the corresponding compositions to Claim 2 of the manufacturing process according to the invention. The alloys of alloy samples Nos. 6 to 11 and 17 to 22 as comparative examples have the compositions which are outside of the ranges of the invention. In each of the alloy samples given in Table 1, Cu having the content of less than 0.05 wt.% is impurities.

Hot mill entrance temperature:	440°C
Reduction per pass at the initial three times of rolling pass :	1.5 %
Reduction per pass from the 4th to 20th rolling pass :	3 to 4%
Reduction per pass on and after the 21st rolling pass :	5 to 40 %
Total pass times :	32 times

With respect to the slab of each alloy sample listed in Tables 1 and 2, each grain diameter before and after homogenization was observed, and the hot workability was compared with one another. The results thus obtained are shown in Tables 3 and 4.

Furthermore, each alloy sheet subjected to hot rolling as described above was subjected to cold rolling up to 1 mm in thickness, and then annealed at 500°C for 10 sec. in a continuous annealing line to manufacture O stocks, which were then respectively applied to a tension test for measuring the mechanical properties. The results thus obtained are shown in Tables 5 and 6.

Table I

Alloy Sample No.	Classifi- cation	Alloy Compositions (Wt.%)											
		Mg	Cu	Be	Mn	Cr	Zr	V	Ti	B	Si	Fe	Al
1	Example of the Invention	5.4	0.02	0.0006	0.03	—	—	0.01	0.01	0.0005	0.04	0.05	Remain- ders
2	"	6.5	0.12	0.0014	—	0.04	—	0.02	0.01	—	0.05	0.08	"
3	"	7.8	—	0.0025	0.01	0.04	0.02	—	0.02	0.0006	0.07	0.03	"
4	"	8.2	0.02	0.0015	0.01	0.01	—	0.02	0.01	0.0007	0.04	0.10	"
5	"	9.4	0.01	0.0020	—	0.08	0.01	—	0.02	0.0008	0.04	0.11	"
6	Comparative Example	7.8	0.05	0.0012	—	0.02	—	0.01	0.002	0.0002	0.04	0.15	"
7	"	8.1	0.06	0.0015	0.01	0.01	0.02	—	0.002	0.000005	0.06	0.12	"
8	"	8.5	0.08	0.0020	0.003	0.001	0.002	—	0.01	0.0005	0.08	0.01	"
9	"	7.8	0.05	0.0010	—	0.003	—	0.002	0.01	0.0005	0.04	0.10	"
10	"	7.8	0.3	0.0025	0.01	0.04	0.02	—	0.02	0.0006	0.28	0.16	"
11	"	8.2	0.01	0.0015	0.01	0.01	—	0.02	0.02	0.0007	0.17	0.35	"

Table 2

Alloy Sample No.	Classifi- cation	Alloy Compositions (Wt.%)											
		Mg	Cu	Be	Mn	Cr	Zr	V	Ti	B	Si	Fe	Al
12	Example of the Invention	5.4	0.42	0.0006	0.03	—	—	0.01	0.01	0.0005	0.04	0.05	Remain- ders
13	"	6.5	0.32	0.0014	—	0.04	—	0.02	0.01	—	0.05	0.08	
14	"	7.8	0.25	0.0025	0.01	0.04	0.02	—	0.02	0.0006	0.07	0.03	
15	"	8.2	0.62	0.0015	0.01	0.01	—	0.02	0.01	0.0007	0.04	0.10	
16	"	9.4	0.78	0.0020	—	0.08	0.01	—	0.02	0.0008	0.04	0.11	"
17	Comparative Example	12.5	0.45	0.0010	0.02	0.02	0.01	0.02	0.01	0.0005	0.04	0.11	"
18	"	8.5	1.4	0.0010	0.01	0.02	—	0.01	0.01	0.0005	0.05	0.10	"
19	"	6.5	0.25	0.0025	0.01	0.04	0.02	—	0.02	0.0006	0.07	0.28	"
20	"	6.5	0.25	0.0025	0.02	0.04	—	—	0.02	0.0006	0.30	0.05	"
21	"	6.5	0.25	0.0025	0.01	0.04	0.01	—	0.02	0.0006	0.30	0.32	"
22	"	4.2	0.20	0.0025	0.02	0.04	0.02	—	0.02	0.0006	0.07	0.09	"

Table 3

All Y Sample No.	Classification	Maximum Grain Diameter (μm) after Casting	Maximum Grain Diameter (μm) after Homogenization	Results of Hot Rolling
1	Example of Invention	170	180	Good and no crack was generated at all.
2	"	85	95	"
3	"	56	60	"
4	"	105	125	"
5	"	245	290	No particular problem although fine cracks of about 2mm in length were generated on both edges.
6	Comparative Example	11000	11500	Slab was largely cracked on both edges at the fifth rolling pass and the subsequent rolling was impossible.
7	"	14000	14500	Slab was largely cracked at the first rolling pass and the subsequent rolling was impossible.
8	"	20000	22500	"
9	"	250	11000	Slab was largely cracked at the second rolling pass and the subsequent rolling was impossible.
10	"	70	80	Cracks of about 30mm in length were generated on both edges.
11	"	95	108	Cracks of about 100mm in length were generated on both edges.

Table 4

Alloy Sample No.	Classification	Maximum Grain Diameter (μm) after Casting	Maximum Grain Diameter (μm) after Homogenization	Results of Hot Rolling
12	Example of the invention	160	170	Good and no crack was generated at all.
13	"	75	85	"
14	"	46	60	"
15	"	100	115	"
16	"	240	270	No particular problem although fine cracks of about 2mm in length were generated on both edges.
17	Comparative Example	140	148	Slab was largely cracked at the first pass and the subsequent rolling was impossible.
18	"	205	215	"
19	"	80	85	Cracks of about 50mm in length were generated on both edges.
20	"	70	72	Cracks of about 30mm in length were generated on both edges.
21	"	70	75	Slab was largely cracked at the tenth rolling pass and the subsequent rolling was impossible.
22	"	85	90	Good and no crack was generated at all.

Table 5

Alloy Sample No.	Classification	Tensile Strength (MPa)	Proof Stress (MPa)	Elongation (%)
1	Example of the Invention	310	125	34
2	Example of the Invention	324	132	37
3	Example of the Invention	348	135	38
4	Example of the Invention	352	140	38
5	Example of the Invention	375	150	39
6-9	Comparative Example	The subsequent cold rolling was impossible due to the cracks caused by hot rolling.		
10	Comparative Example	350	135	28
11	Comparative Example	353	142	26

Table 6

Alloy Sample No.	Classification	Tensile Strength (MPa)	Proof Stress (MPa)	Elongation (%)
12	Example of the Invention	345	130	35
13	Example of the Invention	360	135	37
14	Example of the Invention	368	141	39
15	Example of the Invention	381	150	39
16	Example of the Invention	390	162	40
17-18	Comparative Example	The subsequent cold rolling was impossible due to the cracks caused by hot rolling.		
19	Comparative Example	355	145	29
20	Comparative Example	348	140	27
21	Comparative Example	The subsequent cold rolling was impossible due to the cracks caused by hot rolling.		
22	Comparative Example	275	105	24

As apparent from Tables 3 and 4, all the slabs of alloy samples Nos. 1 to 5, and 12 to 16 having the compositions according to the example of the invention showed satisfactory hot workability. With respect to the alloys of alloy samples Nos. 5 and 16, some fine cracks were generated. However, since the extent of such fine cracks was slight, any bad influence was not exerted upon the industrial manufacture of alloy sheets.

Further, as apparent from Tables 5 and 6, the rolled sheets manufactured from the alloy slabs of alloy samples Nos. 1 to 5 and 12 to 16 are excellent in both strength and elongation.

On the other hand, with respect to the alloy slabs of alloy samples Nos. 6 to 9 with a small content of Ti or both Ti and B, or with a small content of Mn, Cr, Zr and V, the maximum grain diameter after homogenization is not less than 1000 μm and some cracks were generated at the beginning of hot rolling. Thus, the subsequent rolling was impossible.

With respect to the alloys of alloy samples Nos. 17 and 18 with a large content of Mg or Cu, and the alloys of alloy samples No. 21 with a large total content of Fe and Si, cracks were generated during hot rolling, and thus the subsequent rolling was impossible.

With respect to the alloy slabs of alloy samples Nos. 10, 11, 19 and 20 with a large content either Fe and Si, the subsequent rolling was possible even though cracks were generated during rolling. However, the rolled sheets manufactured from these alloys were low in elongation. The elongation of each sheet was less than 30%.

With respect to the alloy of alloy sample No. 22 with a small content of Mg, there is no problem with respect to hot workability. However, the rolled sheet manufactured from this alloy is inferior in both strength and elongation.

Second Example

DC slab from each alloy of alloy samples Nos. 4 (Table 1) and 15 (Table 2) having the compositions according to Example of the invention was homogenized respectively under the different conditions (that is, Case Nos. 23 to 27 and Case Nos. 33 to 37 are based on the homogenization conditions in the manufacturing process).

of the invention, and Case Nos. 28 to 32 and Case Nos. 38 to 42 are based on the homogenization conditions other than those of the invention), as shown in Case Nos. 23 to 32 in Table 7 and Case Nos. 33 to 42 in Table 8. Thereafter, the resultant slab was subjected to hot rolling under the conditions that a hot mill entrance temperature is 380°C and the rolling pass schedule is similar to that of Example 1. Then, the hot workability thereof was compared with one another.

The results thus obtained are shown in Tables 7 and 8.

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Table 7

*Alloy Sample No. 4

Case No.	Classification	Homogenization Conditions		Maximum Grain Diameter (μm) after Homogenization	Results of Hot Rolling
		Temp. ($^{\circ}\text{C}$)	Time (Hr)		
23	Example of the Invention	480	13	75	Good and no crack was generated at all.
24	"	490	7	100	"
25	"	500	2	115	"
26	"	510	1	125	"
27	"	530	1	250	No particular problem although fine cracks of about 3mm in length were generated on both edges.
28	Comparative Example	540	28	25000	Slab was largely cracked at the first rolling pass and the subsequent rolling was impossible.
29	"	550	1	13500	"
30	"	520	30	12000	"
31	"	520	5	1800	Slab was largely cracked on both edges at the second rolling pass and the subsequent rolling was impossible.
32	"	510	4	1250	Slab was largely cracked on both edges at the third rolling pass and the subsequent rolling was impossible.

Table 8

*Alloy Sample No. 15

Case No.	Classification	Homogenization Conditions		Maximum Grain Diameter (μm) after Homogenization	Results of Hot Rolling
		Temp. ($^{\circ}\text{C}$)	Time (Hr)		
33	Example of the Invention	480	13	70	Good and no crack was generated at all.
34	"	490	7	95	"
35	"	500	2	105	"
36	"	510	1	115	"
37	"	530	1	245	No particular problem although fine cracks of about 3mm in length were generated on both edges.
38	Comparative Example	540	28	24000	Slab was largely cracked at the first rolling pass and the subsequent rolling was impossible.
39	"	550	1	12500	"
40	"	520	30	11500	"
41	"	520	5	1500	Slab was largely cracked on both edges at the second rolling pass and the subsequent rolling was impossible.
42	"	510	4	1150	Slab was largely cracked on both edges at the third rolling pass and the subsequent rolling was impossible.

As apparent from Tables 7 and 8, Case Nos. 23 to 27 and Case Nos. 33 to 37 based on the homogenization conditions of the manufacturing process of the invention were all excellent in hot workability.

On the other hand, in Case Nos. 29, 39, in which the temperature for homogenization is too high, and Case

Nos. 28, 30, 38 and 40, in which the time for homogenization is too long, each maximum grain diameter after homogenization was not less than 1000 μm . Therefore, the cracks were generated from the beginning of hot rolling, and the subsequent rolling was impossible.

Furthermore, in Case Nos. 31, 32, 41 and 42, in which each maximum grain diameter after homogenization exceeds 1000 μm , even though the conditions of homogenization might be within the scope of the process of the invention, the cracks were generated during hot rolling to such an extent that the subsequent rolling could not be carried out at the second and third rolling pass.

Example 3

DC slab (thickness: 500 mm, width: 1500 mm and length: 5000 mm) of each alloy of alloy samples Nos. 3 (Table 3) and 14 (Table 2) having the compositions according to Example of the invention was homogenized (the maximum grain diameter : 105 μm) at 480°C for 2 hrs. Thereafter, the resultant slab was subjected to hot rolling up to 5 mm in thickness respectively under the different conditions (including a hot mill entrance temperature and each reduction per pass), as shown in Tables 9 and 10, and the hot workability thereof was compared with one another.

The results thus obtained are shown in Tables 9 and 10.

Table 9

*Alloy Sample No. 3

Case No.	Classification	Hot Mill Entrance Temp. (°C)	Reduction (%) per Pass							Total Pass No.	Result of Hot Rolling
			1st Pass	2nd Pass	3rd Pass	4th Pass	5th Pass	6th Pass	on and after 7th Pass		
43	Example of the Invention	335	1.0	1.1	1.5	2.5	3.5	3.8	Gradually increased 4 - 40	32	Good and no crack was generated at all.
44	"	380	1.5	1.5	2.2	3.5	4.0	4.5	Gradually increased 5 - 40	28	"
45	"	400	1.8	2.2	2.8	4.5	4.6	4.8	Gradually increased 5 - 40	28	"
46	"	445	1.2	2.4	2.0	3.0	4.0	4.0	Gradually increased 5 - 45	22	"
47	"	458	1.5	1.8	2.2	4.0	4.5	5.0	Gradually increased 5 - 45	21	"
48	Comparative Example	480	1.8	2.5	2.5	—	—	—	—	—	Slab was finely cracked at the second pass and largely cracked at the third pass.
49	"	495	1.5	—	—	—	—	—	—	—	Slab was largely cracked at the first pass.
50	"	310	0.5	0.5	0.5	0.4	0.3	0.2	—	—	Deformation resistance was large, reduction was hard, and the subsequent rolling was creased.
51	"	420	4.5	5.0	5.0	—	—	—	—	—	Slab was finely cracked at the second pass and largely cracked at the third pass.
52	"	400	4.0	4.0	4.0	5.0	—	—	—	—	Slab was finely cracked at the third pass and largely cracked at the fourth pass.

Table 10

Case No.	Classification	Hot Mill Entrance Temp. (°C)	Reduction (%) per Pass							Total Pass No.	Result of Hot Rolling
			1st Pass	2nd Pass	3rd Pass	4th Pass	5th Pass	6th Pass	on and after 7th Pass		
53	Example of the Invention	335	1.0	1.1	1.5	2.5	3.5	3.8	Gradually increased 4 - 40	32	Good and no crack was generated at all.
54	"	380	1.5	1.5	2.2	3.5	4.0	4.5	Gradually increased 5 - 40	28	"
55	"	400	1.8	2.2	2.8	4.5	4.6	4.8	Gradually increased 5 - 40	28	"
56	"	445	1.2	2.4	2.0	3.0	4.0	4.0	Gradually increased 5 - 45	22	"
57	"	458	1.5	1.8	2.2	4.0	4.5	5.0	Gradually increased 5 - 45	21	"
58	Comparative Example	480	1.8	2.5	2.5	—	—	—	—	—	Slab was finely cracked at the second pass and largely cracked at the third pass.
59	"	495	1.5	—	—	—	—	—	—	—	Slab was largely cracked at the first pass.
60	"	310	0.5	0.5	0.5	0.4	0.3	0.2	—	—	Deformation resistance was large, reduction was hard, and the subsequent rolling was creased.
61	"	420	4.5	5.0	5.0	—	—	—	—	—	Slab was finely cracked at the second pass and largely cracked at the third pass.
62	"	400	4.0	4.0	4.0	5.0	—	—	—	—	Slab was finely cracked at the third pass and largely cracked at the fourth pass.

As apparent from Tables 9 and 10, Case Nos. 43 to 47 and Case Nos. 53 to 57 based on the rolling conditions of the manufacturing process of the invention were all excellent in hot workability.

On the other hand, in Case Nos. 48, 49, 58 and 59, in which the hot mill entrance temperature is high, and Case Nos. 51, 52, 61 and 62, in which the reduction per pass up to the third rolling pass is high, the cracks were generated at the initial stage of hot rolling.

Further, in Case Nos. 50 and 60, in which the hot mill entrance temperature is low, the deformation resistance was so high that the reduction was hard to be carried out. As a result, the subsequent rolling was ceased.

As described above, according to the process for manufacturing Al-Mg alloy sheets of the invention, the cracks in the Al-Mg alloy sheets with high Mg content, which have the elongation equal to that of the cold rolled steel sheets, can be prevented from being generated at the time of hot rolling, and therefore, the productivity can be largely improved.

Claims

1. A process for manufacturing Al-Mg alloy sheets for press forming, comprising the steps of:
 - homogenization, hot rolling, cold rolling and final annealing of an Al-Mg alloy slab, or intermediate annealing on the way of the cold rolling;
 - wherein the composition of said Al-Mg alloy slab consists of 5 to 10 wt.% of Mg, 0.0001 to 0.01 wt.% of Be, totally 0.01 to 0.2 wt.% of one or more than two species out of Mn, Cr, Zr and V, 0.005 to 0.1 wt.% of Ti, or both 0.005 to 0.1 wt.% of Ti and 0.00001 to 0.05 wt.% of B, Fe and Si as impurities respectively having the content restricted to be less than 0.2 wt.% and the remainders consisting of other inevitable impurities and Al;
 - the maximum grain diameter of said alloy slab is less than 1000 μm ;
 - the homogenization conditions of said alloy slab are set such that a temperature for homogenization is within the range of 450 to 540°C and a time for homogenization is not more than 24 hrs.; and
 - the conditions of said hot rolling are set such that a hot mill entrance temperature is within the range of 320 to 470°C and each reduction per pass of at least the initial three times of rolling passes is not more than 3%.
2. A process for manufacturing Al-Mg alloy sheets for press forming, comprising the steps of:
 - homogenization, hot rolling, cold rolling and final annealing of an Al-Mg alloy slab, or intermediate annealing on the way of the cold rolling;
 - wherein the composition of said Al-Mg alloy slab consists of 5 to 10 wt.% of Mg, 0.05 to 0.8 wt.% of Cu, 0.0001 to 0.01 wt.% of Be, totally 0.01 to 0.2 wt. % of one or more than two species out of Mn, Cr, Zr and V, 0.005 to 0.1 wt.% of Ti, or both 0.005 to 0.1 wt.% of Ti and 0.00001 to 0.05 wt.% of B, Fe and Si as impurities respectively having the content restricted to be less than 0.2 wt.%, and the remainders consisting of other inevitable impurities and Al;
 - the maximum grain diameter of said alloy slab is less than 1000 μm ;
 - the homogenization conditions of said alloy slab are set such that a temperature for homogenization is within the range of 450 to 540°C and a time for homogenization is not more than 24 hrs.; and
 - the conditions for said hot rolling are set such that a hot mill entrance temperature is within the range of 320 to 470°C and each reduction per pass of at least the initial three times of rolling pass is not more than 3%.



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EUROPEAN SEARCH REPORT

Application Number
EP 93 40 2602

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. CL.5)
A	CHEMICAL ABSTRACTS, vol. 117, no. 8, 24 August 1992, Columbus, Ohio, US; abstract no. 74470j, 'Aluminum alloys of high formability' * abstract * & JP-A-3 287 739 (KOBE STEEL LTD) 18 December 1991 ---	1,2	C22C21/06 C22F1/047
A	CHEMICAL ABSTRACTS, vol. 83, no. 6, 11 August 1975, Columbus, Ohio, US; abstract no. 46938d, 'Aluminum alloy excellent in corrosion resistance and strength' * abstract * & JP-A-50 002 844 (SUMITOMO LIGHT METAL INDUSTRIES LTD) 29 January 1975 ---	1,2	
A	DATABASE WPI Derwent Publications Ltd., London, GB; AN 92-223143 'DRAW-WORKING HIGH STRENGTH ALUMINIUM ALLOY PLATE PRODUCTION' & JP-A-4 147 936 (KOBE STEEL LTD) 21 May 1992 * abstract *	1,2	TECHNICAL FIELDS SEARCHED (Int. CL.5) C22C C22F
A	PATENT ABSTRACTS OF JAPAN vol. 16, no. 575 (C-1011) 15 December 1992 & JP-A-04 228 551 (SKY ALUM CO LTD) 18 August 1992 * abstract *	1,2	
A	US-A-3 787 248 (W.C. SETZER ET AL) * claim 1; example 2 * --- -/--	1,2	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 16 December 1993	Examiner Gregg, N
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>I : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons</p> <p>Δ : member of the same patent family, corresponding document</p>			



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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. CL.5)
A	PATENT ABSTRACTS OF JAPAN vol. 16, no. 556 (C-1007) 26 November 1992 & JP-A-04 214 834 (NKK CORP) 5 August 1992 * abstract *	1,2	
A	GB-A-2 245 591 (SKY ALUMINIUM CO LTD) * page 15, line 23 - line 29; claims 1-3 *	1,2	
			TECHNICAL FIELDS SEARCHED (Int. CL.5)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 16 December 1993	Examiner Gregg, N
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons : member of the same patent family, corresponding document</p>			

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